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IRON ORE PELLETS REQUIRING NO INDURATION

D.H.H. Quon and A.K. Kuriakose

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IRON ORE PELLETS REQUIRING NO INDURATION

by

D.H.H. Quon* and A.K. Kuriakose*

ABSTRACT

This paper describes an inorganic cold-bond agglomeration process for making iron ore pellets. Iron ore concentrate fines, sinter-feed and calcium hydroxide are blended together in a mixer and pellets are produced by balling with water. After partial drying, they are hardened with CO_2 in a carbonator. Acceptable crush-strength has been obtained for these pellets, when made using a 60 - 40 concentrator fines - sinter feed mixture with 8% calcium hydroxide.

Keywords: iron ore agglomeration; iron ore pellets; inorganic cold-bonding;

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* Research Scientist, Ceramic Section, Mineral Processing Laboratory, Mineral Sciences Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa.

BOULETTES DE MINERAI DE FER NE NÉCESSITANT PAR D'ENDURCISSEMENT

par

D.H.H. Quon* et A.K. Kuriakose*

RÉSUMÉ

Le rapport fait état d'un procédé d'agglomération minérale à froid utilisé pour fabriquer des boulettes de minerai de fer. Les fines du concentré de minerai de fer, la charge frittée et l'hydroxyde de calcium sont mélangés ensembles dans un malaxeur et agglomérés avec de l'eau pour former les boulettes. Après un séchage partiel, les boulettes sont endurcies au moyen de CO_2, dans une chambre de carbonisation. Les boulettes qui sont fabriquées à l'aide d'un mélange constitué de fines de concentrateur passant la maille 60 - 40, et d'une charge frittée contenant 8 % d'hydroxyde de calcium, démontrent un taux de résistance à l'écrasement acceptable.

Mots-clé : agglomération du minerai de fer; boulettes de minerai de fer; agglomération minérale à froid

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*Chercheur scientifique, Section de la céramique, Laboratoire de traitement des minéraux, Laboratoires des sciences minérales, CANMET, Énergie, Mines et Ressources Canada, Ottawa.

INTRODUCTION

The bonding of iron ore concentrates at low ambient temperatures is known as the cold-bond pelletizing process. This process is different from the conventional ones in that the hardening of the green pellets is achieved by the action of additives with high strength bonding properties (1-7). Such products differ from thermally indurated pellets in that the bonding mechanisms are based on hydraulic or hydrothermal reaction at normal temperatures (or to about 250°C) rather than by high temperature sintering. The advantages of this process are substantial - the induration of the green pellets at a temperature of 1300°C can be eliminated, resulting in a reduction in cost of iron ore pellet production achieved through reduced energy consumption, and capital and maintainance expenditures on high temperature furnaces. Three types of cold-bonding processes have been reported in the literature for iron ore pellets. They are:

1. The Grangcold process using portland cement as a binder (3);

2. The COBO and MTU cold-bond processes using lime and silica as the bonding ingredients which form calcium silicate bonds under hydrothermal conditions (4); and

3. The carbonate bonding process which forms calcium carbonate bonds by the reaction of calcium hydroxide and carbon dioxide (7).

The carbonate-bonding process was originally developed by the Blocked Iron Ore Corporation, New York, for agglomeration of steel-plant by-products and iron ore concentrates (7). Imperato reported that the carbonate-bonded pellets developed satisfactory

physical and chemical properties and also performed satisfactorily in the blast furnace.

In the carbonate bonding process, the hardening of the pellets occurs through the reaction between calcium hydroxide and carbon dioxide to form calcium carbonate ($CaCO_3$) and/or calcium bicarbonate ($Ca(HCO_3)_2$) bonds which provide the strength. Normally, the strength of the calcium carbonate bond is higher than that of calcium bicarbonate. Other factors which influence the bonding strength of the pellets are the lime content, moisture and particle size of the ore and the extent of carbonation.

A preliminary investigation of the use of the carbonate-bonding process for the agglomeration of Canadian iron ore concentrate fines was conducted earlier at CANMET (6). The results of that study indicated that the maximum strength was developed in the pellets containing 12% calcium hydroxide, but was only about 740N, considerably below the 2000N specified by the ISO. It appeared that the low strength obtained was due to the fine grained nature of the concentrate which hindered the infiltration and reaction of the CO_2 with the $Ca(OH)_2$. This paper reports the effect of using a mixture of sinter feed (which is relatively coarse) and fine iron ore concentrate in making the cold-bonded pellets with lime and carbonation, and the resulting strength-development in the pellets.

EXPERIMENTAL

Materials

Iron ore concentrates and sinter feeds

The iron ore concentrate used for the experimental work was obtained from the Mt. Wright deposits and the sinter feed was supplied by Quebec Cartier Mining Company. The iron ore fines and the sinter feed both consisted of principally hematite and variable amounts of magnetite. The size distribution of the sinter feed is given in Table 1.

Calcium hydroxide

Certified reagent grade calcium hydroxide was used for the experiments.

Procedure

Normally a 2 kg batch of mix with variable amounts of concentrate fines and sinter feed was prepared with the required amount of calcium hydroxide. The mixing was carried out in a Turbula mixer*.

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*Manufactured by W.A. Bachofen, Switzerland

Pellet preparation

Spherical pellets were prepared from the mix by the balling technique using a rotating tire pelletizer. Seed pellets were initially made and were then used to initiate pellet growth by the continous addition of dry mix and water to the system until the desired pellet size was obtained. The final pellets were -12.5 mm +11.2 mm (-1/2" +7/16") in size (screened).

Testing

The as-prepared pellets were characterized by the drop test and wet compressive strength. The compressive strength of the product was determined after the pellets were subjected to different carbonation times.

Carbonator

The carbonator vessel used for the carbonation process was a tower reactor. In this process the pellets were placed in a cylindrical glass tower 2.5 cm in diameter x 15 cm high, and carbon dioxide was continuously fed from the top to the bottom through the pellet bed. The water produced in the carbonation reaction automatically drained from the tower.

RESULTS

Table 2 gives the various proportions of fine concentrate, sinter feed and calcium hydroxide used for the pelletization experiments. Difficulties were encountered during the pelletization because of the variability in the amount of water

required for the process from batch to batch due to the different proportions of materials used for the experimental work. The required water content for the green pellets varied between 7 and 9 wt% .

Optimization of sinter feed and concentrate fines for pelletization

Attempts made first to pelletize the iron ore sinter feed alone with calcium hydroxide were unsuccessful due to the platy nature of the specular hematite. However, by adding concentrate fines to the sinter feed, balling occurred without difficulty. It was observed that good pellets could be obtained by adding 40 to 70 weight percent of the concentrate fines to the sinter feed.

Physical characteristics of the green pellets

The drop number and wet crushing strength of the green pellets determined are included in Table 2. There is no correlation between the drop number and the content of fines or the calcium hydroxide in the green pellets. In the green crushing strength test, the strength developed in the pellets containing higher amounts of calcium hydroxide is slightly higher.

Effect of carbonation time on the strength development of the pellets

To develop good pellet crushing strength, the excess water remaining in the pellets after the balling must be reduced prior to the exposure to carbon dioxide (6). A moisture content of about 6 wt% appears to be optimum (6). The water content of the

pellets used for carbonation in the present work is given in Table 3. These pellets were subjected to carbonation time varying from 1 to 148 hours. The strength increased with increasing carbonation time and reached a maximum between 48 to 72 h. No strength increase was observed beyond 72 h carbonation time.

The effect of calcium hydroxide content of the pellets on crushing strength

The variation of strength versus calcium hydroxide content in the pellets made from the mixture of fine concentrate and sinter feed is illustrated in Table 3. The results indicate that the highest average crushing strength is developed in batches containing 8 to 10 wt% calcium hydroxide. There is a relationship between the calcium hydroxide content and fines content. At 6, 8 and 10 wt% calcium hydroxide, the corresponding optimum fines contents are respectively 70, 60 and 50 wt% A mixture of 40 wt% sinter feed and 60 wt% concentrate fines with 8 wt% calcium hydroxide gives the strongest pellets with an average crush strength over 2000 N required by ISO specifications. However, it should be noted that although only these conditions yielded this high average strength value, there are several other compositions which show individual pellet strengths over 2000 N.

DISCUSSION

The role of calcium hydroxide and carbon dioxide in the bonding process

The use of calcium hydroxide in building materials has been in practice for many centuries. The principle there is the same - hardening of calcium hydroxide by the formation of calcium carbonate through the action of carbon dioxide from the atmosphere during the course of days and months. In the laboratory the hardening process is accelerated by using pure carbon dioxide.

The formation of calcium carbonate from calcium hydroxide and carbon dioxide is dependent on the water content in the system. The reaction itself produces water as a by-product according to the equation:

$$Ca(OH)_2 + CO_2 + \longrightarrow CaCO_3 + H_2O$$

However, if there is excess water present or if the water remains in the system, carbon dioxide can react further with the carbonate product to form calcium bicarbonate:

$$CaCO_3 + CO_2 + H_2O \longrightarrow Ca(HCO_3)_2$$

While the bonds formed by the insoluble calcium carbonate are strong, the bonds formed by the soluble calcium bicarbonate are weak and unstable. This is the reason why the pellets have to be partially dried before carbonation, and the water produced removed during the process in order to produce strong pellets.

The reaction is exothermic and the heat produced helps eliminate the water produced in the system. A moisture of about 6% appears to give optimum strength development.

The effect of sinter feed in the pelletizing mix

The effect of the addition of sinter feed to the iron-ore concentrate fines is analogous to the effect of aggregates in concrete in which both fine and coarse aggregates are combined together with portland cement to develop increased compressive strength. In this case, the addition of coarse material provides porosity for the CO_2 to infiltrate into the pellets and to react with calcium hydroxide to form calcium carbonate bonding of the iron ore, and also increase its compressive strength through increased overall hardness of the product.

CONCLUSIONS

Iron ore concentrate fines (-44 μm) mixed with sinter feed and calcium hydroxide can be pelletized by the balling technique. After partial drying in an oven at 100°C to about 6% moisture content, certain compositions can be hardened in CO_2 to crushing strengths over 2000 N (ISO standard). A combination of the right proportions of fine and coarse iron ore materials and calcium hydroxide is required for proper strength development. A mixture containing 40% sinter feed, 60% concentrate fines and 8% calcium hydroxide produces the strongest pellets under the conditions of size (-12.5, + 11.2 mm), moisture content (6%) and carbonation time (72 h) in the present study.

RECOMMENDATIONS

In view of the satisfactory strength obtained for certain compositions in the system, it is recommended that further work be carried out in order to determine the limits of composition and other conditions for the production of pellets meeting ISO specifications. This will accelerate the transfer of this technology to industry. Also, information on the mechanical degradation and reducibility of the material should be obtained.

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Table 1: Size Distribution of the Sinter Feed

Size, (mesh)	%
14	1.76
20	5.44
28	10.30
35	14.75
48	17.72
65	16.08
100	15.95
150	9.35
200	5.64
-200	3.60

Table 2: Physical Properties of the Green Pellets

Sinter feed, wt.%	Concentrate fine, wt.%	Ca(OH)2, wt.%	Drop number	Wet strength, N
30	70	6	4	24
40	60	6	5	24
50	50	6	5	29
60	40	6	8	18
30	70	8	4	24
40	60	8	5	26
50	50	8	6	15
60	40	8	10	19
30	70	10	4	24
40	60	10	5	33
50	50	10	6	33
60	40	10	5	33

Table 3: Strength Development of the Pellets Versus Carbonation Times

Sinter feed,%	Concentrate fines, %	$Ca(OH)_2$ %	Moisture %	Average Compressive Strength (N) at Carbonation Time (h) 1	24	48	72	Strength Range (N) at 72 h
30	70	6	5.6	147	167	1303	1686	1274-2156
40	60	6	5.8	156	1342	1058	1453	1176-1765
50	50	6	5.7	303	411	1411	1478	1078-1862
60	40	6	5.8	303	421	902	1098	882-1274
30	70	8	6.0	392	1196	1774	1803	1470-2352
40	60	8	6.4	118	637	1437	2107	1764-2450
50	50	8	5.8	339	559	1303	1247	1078-1569
60	40	8	6.2	78	333	1019	1430	1176-1569
30	70	10	5.0	352	696	1411	940	784-1176
40	60	10	6.0	264	891	1480	1783	1568-2255
50	50	10	6.0	254	627	1195	1901	1569-2548
60	40	10	5.0	372	1254	1440	1370	980-1568